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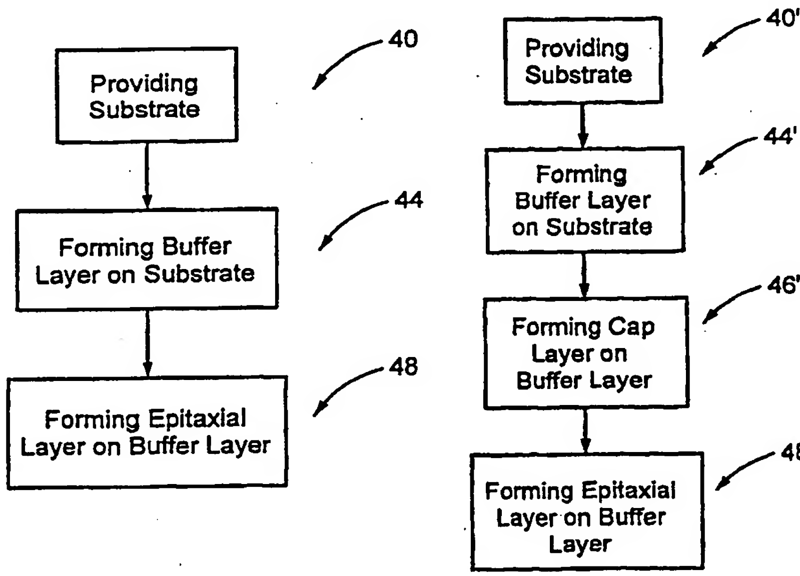

(57) Abstract

A method for forming an epitaxial layer (4) involves depositing a buffer layer (2) on a substrate (1) by a first deposition process, followed by deposition of an epitaxial layer (4) by a second deposition process. By using such a dual process, the first and second deposition processes can be optimized, with respect to performance, growth rate, and cost, for different materials of each layer. A semiconductor heterostructure prepared by a dual deposition process includes a buffer layer (2) formed on a substrate by MOCVD, and an epitaxial layer (4) formed on the buffer layer (2), the eptitaxial layer deposited by hydride vapor-phase deposition.

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DUAL PROCESS SEMICONDUCTOR HETEROSTRUCTURES & METHODS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the growth of epitaxial films. The invention also relates to the growth of a buffer layer on a substrate and the growth of an epitaxial film on the buffer layer. The invention further relates to the epitaxial deposition of heterostructures by more than one growth technique. The invention still further relates to a two stage, or dual, process for growing gallium nitride and related materials epitaxial layers.

2. Background of the Related Art

Gallium nitride (GaN) and its related nitrides, including AlN, InN and alloys of these materials, are emerging as important technological material. For example, GaN is currently used in the manufacture of blue light emitting diodes, semiconductor lasers, and other opto-electronic devices. However, it is currently impossible to fabricate bulk GaN crystals of usable size as substrates in semiconductor manufacturing. Thus, GaN films are made by deposition on a non-native substrate material, typically sapphire (Al_2O_3). However, a large lattice mismatch

and thermal mismatch exists between the Al_2O_3 substrate and the GaN layer. As a result, the material has large dislocation densities, which limit the performance of devices fabricated from these films, and at the same time restricts the applications for such GaN structures.

According to a prior art method for growing higher-quality GaN films, a relatively thick layer of an intermediate material can first be grown on the substrate as a buffer layer, and the GaN layer can then be grown on the buffer layer. Defects in GaN layers grown directly on sapphire substrates are due to major differences in inter-atomic spacing (lattice constant) and coefficient of thermal expansion (CTE) between the substrate and GaN. Therefore, if the buffer layer has a lattice constant and CTE closer to those of GaN, the GaN (top) layer will have fewer defects, and will be of higher quality. High quality GaN layers are necessary for electronic and opto-electronic devices. A material which meets the desired lattice constant and CTE criteria is aluminum nitride (AlN).

Prior art methods of fabricating heterostructures, having a GaN layer on a buffer layer, have used the same growth technique for both layers. For example, both semiconductors (the AlN buffer

layer and the GaN layer) can be grown by metal-organic chemical vapor deposition (MOCVD). In this technique, ammonia gas (NH_3) is reacted with a metallo-organic compound containing aluminum or gallium, such as trimethyl aluminum (TMA), triethyl aluminum (TEA), trimethyl gallium (TMG), or triethyl gallium (TEG). The reaction occurs at high temperatures in the vicinity of a substrate, and a solid product (GaN or AlN) is deposited on the substrate. However, this technique is not only expensive, but also slow. In particular, the metallo-organic source materials are costly, and they can only be delivered to the substrate for reaction at low rates.

A currently favored prior art technique for the growth of relatively thick layers, e.g., of GaN, is HVPE. In this process, growth proceeds due to the high-temperature vapor-phase reaction between gallium mono-chloride (GaCl) and ammonia. The ammonia is supplied from a standard gas source, while the GaCl is produced by passing hydrogen chloride (HCl) gas over a liquid gallium (Ga) supply. Using this method, GaN can be grown relatively quickly and inexpensively. Further, GaN grown at a fast rate may produce layers with less defect densities.

However, due to difficulties involved in providing a supply of aluminum chloride (AlCl), HVPE cannot be used for the efficient growth of an AlN buffer layer. (For example, when HCl is passed over Al metal, the AlCl that is formed immediately solidifies, and is not carried towards the substrate.) Consequently, AlN layers must be grown by techniques other than HVPE, such as MOCVD.

The above delineated disadvantages associated with prior art methods for deposition of AlN/GaN heterostructures are addressed by the present invention, in which a buffer layer (e.g., AlN) and an epitaxial layer (e.g., GaN) are grown using different techniques, as will be described fully hereinbelow.

SUMMARY OF THE INVENTION

In view of the above, it is an object of the present invention to provide a semiconductor heterostructure and method of making the same.

One feature of the invention is that it provides a two-stage process for fabricating a semiconductor heterostructure.

Another feature of the invention is that it provides a semiconductor heterostructure prepared by growing an epitaxial nitride layer on a buffer layer, the buffer layer deposited by a technique other than HVPE.

Another feature of the invention is that it provides a method of growing a semiconductor heterostructure, wherein a buffer layer is first grown on a substrate by metallo-organic chemical vapor deposition, and an epitaxial layer is subsequently grown on the buffer layer by hydride vapor-phase epitaxy.

Another feature of the invention is that it provides an epitaxial nitride layer formed on a substrate formed by MOCVD.

One advantage of the invention is that it provides a method for

fabricating a semiconductor heterostructure by two different deposition processes, wherein each process is optimized for the material to be deposited.

Another advantage of the invention is that it provides an epitaxial layer formed by HVPE on a buffer layer formed by MOCVD.

Another advantage of the invention is that it provides an efficient method for forming an epitaxial nitride layer suitable for electronic and opto-electronic devices.

These and other objects, advantages and features are accomplished by the provision of a method of making a semiconductor heterostructure, including the steps of: a) providing a substrate; b) forming a buffer layer on the substrate to form a buffer-layered substrate; c) forming a cap layer on the buffer layer; and d) forming an epitaxial layer on the cap layer, wherein the buffer layer is formed by MOCVD, MBE or other suitable CVD techniques, and the epitaxial layer is formed by HVPE or other suitable techniques.

These and other objects, advantages and features are accomplished by the provision of a semiconductor heterostructure, including: a

buffer layer, said buffer layer formed by MOCVD; and an epitaxial layer disposed on said buffer layer, said epitaxial layer formed by HVPE.

These and other objects, advantages and features are accomplished by the provision of an epitaxial layer prepared according to a method including the following steps: a) forming a buffer layer on a substrate by MOCVD , MBE or other suitable CVD techniques; b) forming a cap layer on the buffer layer; and c) forming an epitaxial layer on the cap layer by hydride vapor-phase epitaxy.

These and other objects, advantages and features of the invention will be set forth in part in the description which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention. The advantages of the invention may be realized and attained as particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. **1** schematically represents a MOCVD system suitable for forming a cap layer and a buffer layer on a substrate during a first deposition process;

Fig. **2** schematically represents a HVPE system suitable for forming an epitaxial layer on a buffer layer during a second deposition process;

Figs. **3A, 3B, 3C,** and **3D** represent sequential stages in fabrication of a semiconductor heterostructure, according to the invention;

Fig. **4A** schematically represents a series of steps involved in a method of making a semiconductor heterostructure, according to the invention; and

Fig. **4B** schematically represents a series of steps involved in a method of making a semiconductor heterostructure, according to another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

For purposes of illustration, the invention will be described primarily in relation to the fabrication of a heterostructure having a GaN epitaxial layer deposited on an AlN buffer layer, wherein the buffer layer is deposited by MOCVD. However, it is to be understood that the invention is also applicable to the deposition of materials other than GaN, and to deposition of buffer layers by techniques other than MOCVD.

Referring now to the drawings, Fig. **1** schematically represents a MOCVD system **6** suitable for depositing at least a buffer layer on a substrate during a first deposition process of the invention. According to a currently preferred embodiment of the invention, system **6** may also be used for depositing a cap layer on buffer layer **2** (**Figs. 3A-3D**). MOCVD systems of the type schematically represented in Fig. **1** are well known in the art. Briefly, system **6** includes a chamber **8**, at least part of which is surrounded by a heating unit **16**. A substrate **14**, arranged within chamber **8**, is heated by means of heating unit **16**. Ammonia is provided from a standard gas source **13**. Vapor of a metallo-organic compound is supplied by passing a carrier gas **17**, typically nitrogen or hydrogen, through a liquid supply of the metallo-organic compound contained within a bubbler **15**. The metallo-organic compound is an

aluminum- or gallium containing metallo-organic compound, such as trimethyl aluminum (TMA), triethyl aluminum (TEA), trimethyl gallium (TMG), or trimethyl gallium (TEG). The metallo-organic compound supply is heated, and the flow of carrier gas **17** is regulated to provide a stream of gas which is saturated with vapor of the metallo-organic compound. The ammonia and the vapor of the metallo-organic compound are introduced into chamber **8**. Deposition of AlN or GaN occurs at the surface of substrate **14** due to the high temperature vapor-phase reaction of the metallo-organic compound with the ammonia gas. Naturally, for the deposition of AlN (e.g., a buffer layer **2**, Fig. **3B**) the metallo-organic (or organo-metallic) compound in bubbler **15** is an aluminum-containing organo-metallic, while for the deposition of GaN (e.g., a cap layer **3**, Fig. **3C**) the organo-metallic compound in bubbler **15** is a gallium-containing organo-metallic.

Fig. **2** schematically represents a HVPE system **18** suitable for forming an epitaxial layer **4** on a buffer layer **2**, or cap layer **3**, (Figs. **3B-3D**) during a second deposition process of the invention. HVPE systems (e.g., **18**) suitable for forming an epitaxial layer during a second deposition process of the invention are well known in the art. Briefly, system **18** includes a growth tube or reactor **21** having wall **23**, inlet **22**, and outlet

19, and a GaCl delivery system **26**. System **18** may be contained entirely within a heat source, e.g., a furnace **24**. Epitaxial deposition on heated substrate **14** proceeds by the vapor-phase reaction of source or reagent gases which are introduced into reactor **21**. For example, a reagent gas, such as gallium monochloride and indium monochloride, may be projected towards substrate **14** via reaction assembly **26**; while ammonia may be introduced into growth tube **21** through reactor inlet **22**. Reagent gas, e.g. GaCl, may be formed in reaction assembly **26** by passing HCl over liquid metal (e.g., gallium) at high temperatures. The direction of gas flow is indicated by arrow **5**. Reagent gases (e.g., GaCl and InCl) react with ammonia within growth tube **21** to form the respective nitride, GaN and InN, which is deposited on substrate **14**.

HVPE is a much more cost-effective technique for GaN deposition than is MOCVD, the latter technique requiring costly metallo-organic reagents an multiple temperature devices for each reagent source. In addition, a larger growth rate of the nitride epitaxial layer can be achieved using a HVPE system as compared with an MOCVD system. This is so because, in the case of the former system, Ga can be supplied to the substrate more quickly.

Figs. **3A, 3B, 3C,** and **3D** represent stages in fabrication of a semiconductor heterostructure, according to the invention. Fig. **3A** represents a substrate **1**. Materials suitable, generally for the fabrication of semiconductor devices are well known in the art. However, according to the invention, substrate **1** is preferably a material such as sapphire, silicon, silicon carbide, and gallium arsenide, zinc oxide, magnesium oxide, or the like.

Fig. **3B** represents a buffer layer **2** formed on substrate **1**. According to the invention, buffer layer **2** is formed on substrate **1** by MOCVD, chemical vapor deposition (CVD), or molecular beam epitaxy (MBE). Each of these techniques are well known in the art. Buffer layer **2** may be deposited on substrate **1** to a thickness in the range of 1.0 nanometer to about 1.0 Micron. According to a currently preferred embodiment of the invention, buffer layer **2** is formed on substrate **1** by MOCVD. Preferably, buffer layer **2** includes AlN, GaAlN, InGaN or GaN.

Fig. **3C** represents a cap layer **3** formed on buffer layer **2**. According to the invention, cap layer **3** is formed on buffer layer **2** by MOCVD, CVD, or MBE. According to a currently preferred embodiment of the invention, cap layer **3** is formed on buffer layer **2** by MOCVD. Preferably, cap layer **3** is formed using the

same process and system as that used for forming buffer layer **2**, with the exception that a different organo-metallic reagent may be used in bubbler **15**. Preferably the cap layer **3** is formed on the buffer layer **2** in a continuos fashion over the buffer layer **2** to eliminate surface degradation of the buffer layer **2**.

Cap layer **3** preferably includes a nitride of an element of groups III, IV or V of the periodic table. More preferably, cap layer **3** includes GaN. Cap layer **3** serves to protect buffer layer **2** against degradation and exposure to the atmosphere upon removal from chamber **8** of MOCVD system **6** (Fig. **1**). Cap layer **3** may be deposited on buffer layer **2** to a thickness of 1.0 Nanometer to 1000 Nanometer. In situations where an inert (e.g., dry, oxygen-depleted) atmosphere is provided, a cap layer **3** may be unnecessary.

Fig. **3D** represents an epitaxial layer **4** formed on buffer layer **2**. Epitaxial layer **4** has the same composition as cap layer **3** (Fig. **3C**), and cap layer **3** therefore merges with, or is integrated with, epitaxial layer **4**. However, whereas cap layer **3** is formed by MOCVD, CVD, or MBE, epitaxial layer **4** is formed by HVPE (e.g., using system **18**, Fig. **2**). Epitaxial layer **4** may be deposited on substrate **1** to any thickness, but is typically deposited to a

thickness in the range of about 1.0 Micron to about 500 Micron (inclusive of cap layer **3** integrated with layer **4**). According to a currently preferred embodiment of the invention, epitaxial layer **4** includes GaN. Epitaxial layer **4** and buffer layer **2** preferably have a combined thickness in the range of about 1.0 Micron to about 500 Micron.

Fig. **4A** schematically represents a series of steps involved in a method of making a semiconductor heterostructure, according to the invention, in which step **40** involves providing a substrate. The substrate provided in step **40** is preferably a substrate composed of a material such as sapphire, silicon, silicon carbide, or gallium arsenide. Step **44** involves forming a buffer layer on the substrate to provide a buffer-layered substrate. The buffer layer may be formed on the substrate by a first deposition process of the method, such as MOCVD, CVD, or MBE. The first deposition process of step **44** is optimized specifically for the particular component(s) of the buffer layer.

The buffer layer deposited in step **44** preferably includes a material having lattice constant and CTE values similar to those of an epitaxial layer to be formed on the buffer layer (step **48**, hereinbelow). The buffer layer formed in step **44** preferably has a

thickness in the range of about 1.0 nanometer to about 1.0 micron. Step **48** involves forming the epitaxial layer on the buffer layer. The epitaxial layer formed in step **48** is formed by a second deposition process, wherein the second deposition process is optimized specifically for the particular component(s) of the epitaxial layer. The components of the epitaxial layer preferably include a nitride of an element of group III or IV of the periodic table, or a mixture of two or more such nitrides. According to a currently preferred embodiment, the epitaxial layer deposited on the buffer layer includes GaN and is formed by HVPE.

Fig. **4B** schematically represents a series of steps involved in a method of making a semiconductor heterostructure, according to another embodiment of the invention, in which steps **40'** and **44'** are analogous to steps **40** and **44** described hereinabove with reference to Fig. **4A**. After step **44'**, a cap layer may be formed on the buffer layer. The cap layer serves to protect the buffer layer from exposure of the buffer layer to the atmosphere prior to deposition of an epitaxial layer on the buffer layer. The cap layer may be formed on the buffer layer by a deposition process such as MOCVD, CVD, or MBE. Preferably, the cap layer is formed on the buffer layer by the same deposition process as is used for

forming the buffer layer in step **44'**. Preferably, the material deposited to form the cap layer is the same as the material to be deposited to form the epitaxial layer in a subsequent step (step **48'**), such that the cap layer is integrated with the epitaxial layer. However, the epitaxial layer formed in step **48'** is deposited by a second deposition process, preferably HVPE.

By using different deposition processes for forming the buffer and epitaxial layers, each deposition process can be optimized for the particular material to be deposited. According to a currently preferred embodiment of the invention, the cap and epitaxial layers are GaN, and are formed on a buffer layer of AlN.

After formation of the epitaxial layer on the buffer layer, the epitaxial layer and/or the buffer layer may be removed from the substrate as a combined epitaxial layer/buffer layer heterostructure. Further, any portion of the heterostuctures described herein may be removed after the deposition processes. The epitaxial layer/buffer layer heterostructure may then itself serve as a platform or substrate for further deposition and/or device processing.

For purposes of illustration, the invention has been described primarily in relation to a semiconductor heterostructure having a GaN epitaxial layer deposited on an AlN buffer layer, wherein the buffer layer is deposited by MOCVD and the GaN layer is deposited by HVPE. However, the invention is also applicable to deposition techniques other than MOCVD, and to the deposition of epitaxial layers other than GaN. For example, buffer layers may be deposited by CVD or MBE; and epitaxial layers may be formed from nitrides of other elements of groups III and IV of the periodic table.

The foregoing embodiments are merely exemplary and are not to be construed as limiting the present invention. The present teaching may be applied to other types of apparatuses and methods. The description of the present invention is intended to be illustrative, and not to limit the scope of the appended claims. Many alternatives, modifications, and variations will be apparent to those skilled in the art.

WHAT IS CLAIMED IS:

1. A method of making a semiconductor heterostructure, comprising the steps of:

a) providing a substrate;

b) forming a nitride buffer layer on the substrate to form a buffer-layered substrate, wherein the buffer layer is formed by a first deposition technique; and

c) forming an nitride epitaxial layer on the buffer layer, wherein the epitaxial layer is deposited by a second deposition technique, and the second deposition technique is different from the first deposition technique.

2. The method of claim 1, wherein said step b) comprises forming the buffer layer by MOCVD.

3. The method of claim 1, wherein said step c) comprises forming the epitaxial layer by hydride vapor-phase epitaxy.

4. The method of claim 1, wherein the epitaxial layer comprises a nitride of an element of groups III and IV of the periodic table.

5. The method of claim 1, wherein the substrate comprises a material selected from the group consisting of sapphire,

silicon, silicon carbide, and gallium arsenide, and the buffer layer comprises aluminum nitride, ZnO, MgO and GaN.

6. The method of claim 1, wherein the epitaxial layer comprises metal nitride comprising at least one metal selected from the group consisting of gallium, aluminum and indium.

7. The method of claim 1, wherein the buffer layer has a thickness of at least 1.0 micron.

8. The method of claim 1, wherein the epitaxial layer has a thickness of at least 1 micron to 500 micron.

9. The method of claim 1, further comprising the step of:

d) *in lieu of* said step c) and after said step b), forming a cap layer on the buffer layer; and

e) forming the epitaxial layer on the cap layer.

10. The method of claim 9, wherein said step d) is performed by MOCVD and said step e) is performed by HVPE.

11. The method of claim 9, wherein the cap layer comprises a nitride of an element of groups III and IV of the periodic

table.

12. The method of claim 9, wherein the cap layer and the epitaxial layer each comprise a metal nitride comprising at least one metal selected from the group consisting of gallium, aluminum, and indium.

13. The method of claim 1, wherein said step b) is performed in a MOCVD chamber, and said step c) is performed in a HVPE reactor, and said method further comprises the steps of:

f) after said step b), removing the buffer-layered substrate from the MOCVD chamber; and

g) arranging the buffer-layered substrate in the HVPE reactor.

14. A method of making a semiconductor heterostructure, comprising the steps of:

a) providing a substrate;

b) forming a buffer layer on the substrate to form a buffer-layered substrate;

c) forming a cap layer on the buffer layer; and

d) forming an epitaxial layer on the cap layer, wherein the buffer layer is formed by CVD and the epitaxial layer is formed by HVPE.

15. The method of claim 14, wherein said step c) is performed by MOCVD.

16. The method of claim 14, further comprising the step of:

e) removing a portion of the heterostructure from the substrate.

17. The method of claim 14, wherein the substrate comprises a material selected from the group consisting of sapphire, silicon, silicon carbide, and gallium arsenide; the buffer layer comprises AlN; and the epitaxial layer comprises GaN.

18. The method of claim 14, wherein the buffer layer and the epitaxial layer have a combined thickness in the range of 1.0 micron to 500 micron.

19. The method of claim 14, wherein the epitaxial layer has a thickness in the range of 1.0 micron to 500 micron.

20. An epitaxial layer, comprising a metal nitride comprising a metal selected from the group consisting of gallium, aluminum and, wherein the epitaxial layer is formed by hydride vapor-phase deposition on a buffer layer and wherein the buffer layer comprises a nitride of an element of groups III or IV of the periodic table formed on a substrate by a MOCVD.

21. The epitaxial layer of claim 20, wherein said epitaxial layer is removed from said buffer layer.

22. The epitaxial layer of claim 20, wherein said epitaxial layer and the buffer layer together comprise an epitaxial layer/buffer layer heterostructure, and the epitaxial layer /buffer layer heterostructure is removed from the substrate.

23. A semiconductor heterostructure, comprising:

a) a buffer layer, said buffer layer formed by MOCVD; and

b) an epitaxial layer deposited on said buffer layer, said epitaxial layer formed by HVPE.

24. The heterostructure of claim 23, wherein said buffer layer comprises a material selected from the group consisting of AlN, InN and GaN, and wherein said buffer layer has a

thickness in the range of from about 1.0 nanometer to 1.0 micron.

25. The heterostructure of claim 23, wherein said epitaxial layer comprises a metal nitride comprising at least one metal selected from the group consisting of Ga, Al and In and wherein said epitaxial layer has a thickness in the range of from about 1.0 micron to 500 micron.

26. An epitaxial layer prepared according to the method of:

a) forming a buffer layer on a substrate by CVD;

b) forming a cap layer on the buffer layer; and

c) forming an epitaxial layer on the cap layer by hydride vapor-phase epitaxy.

27. The epitaxial layer of claim 26, wherein the epitaxial layer comprises a nitride comprising an element selected from group III and group IV of the periodic table.

28. The epitaxial layer of claim 26, wherein the substrate comprises a material selected from the group consisting of sapphire, silicon, silicon carbide, gallium arsenide, zinc oxide and magnesium oxide; and the buffer layer comprises aluminum nitride.

29. The epitaxial layer of claim 28, wherein the cap layer and the epitaxial layer have substantially the same composition.

30. The epitaxial layer of claim 26, wherein the cap layer and the epitaxial layer each comprise a nitride comprising an element selected from the group consisting of group III and group IV elements of the periodic table.

31. The epitaxial layer of claim 26, wherein the cap layer is formed by MOCVD.

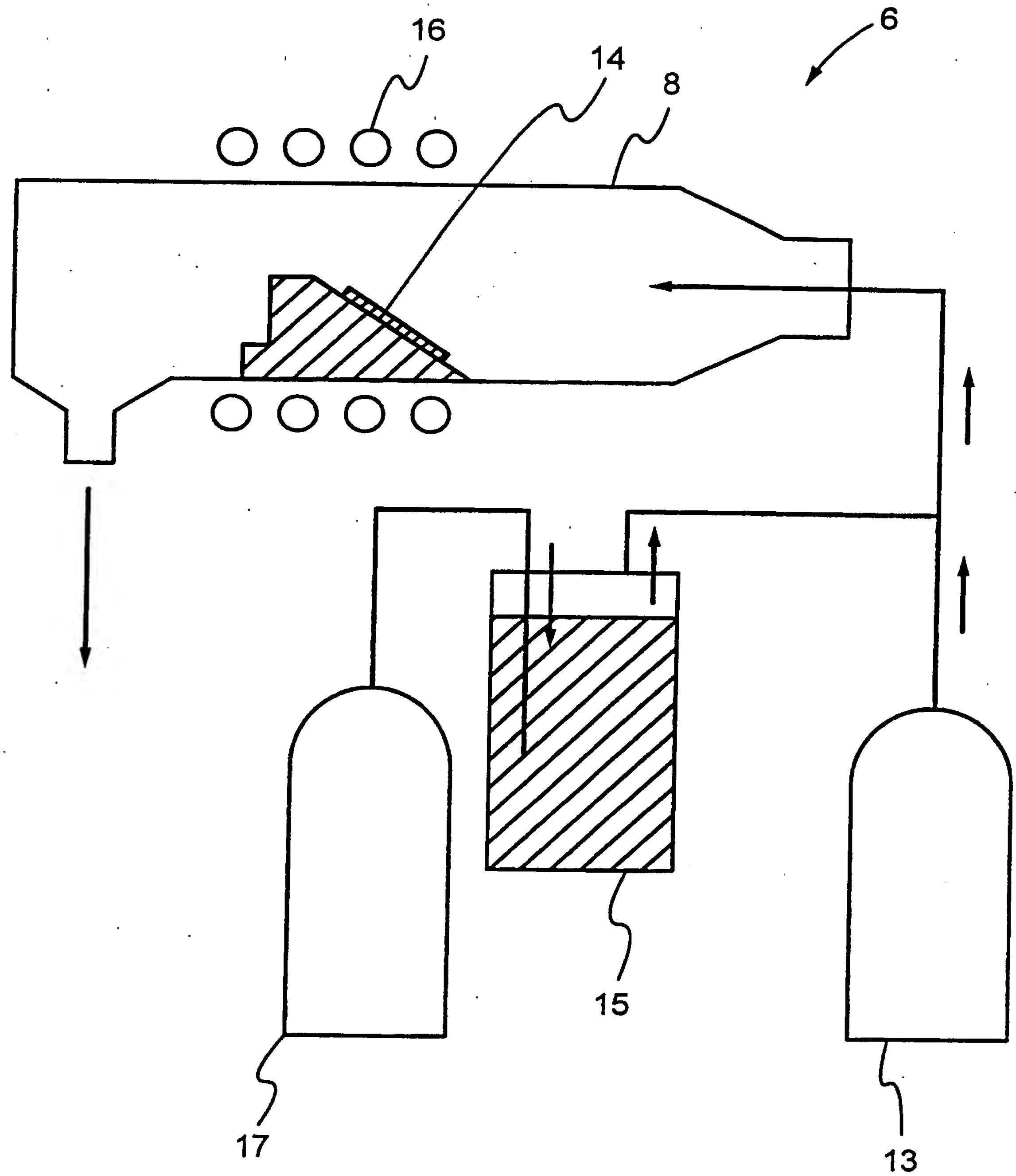


FIG. 1 PRIOR ART

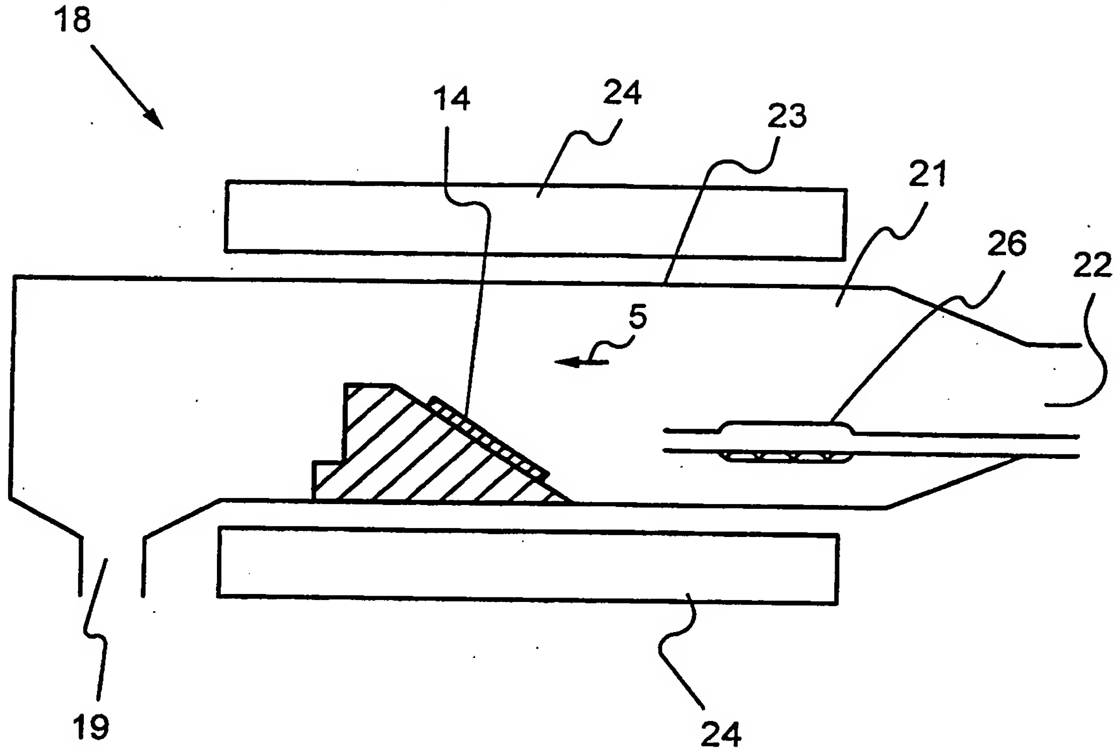


FIG. 2 PRIOR ART

FIG. 3A

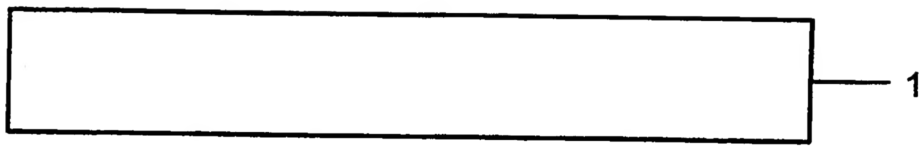


FIG. 3B

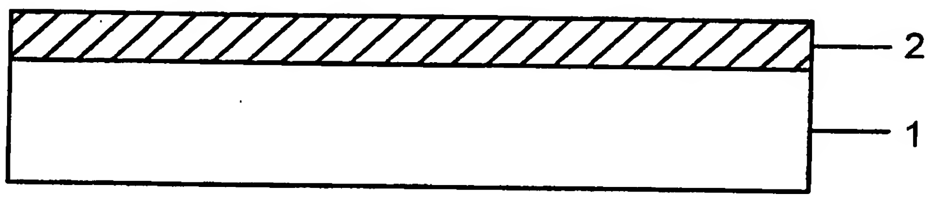


FIG. 3C

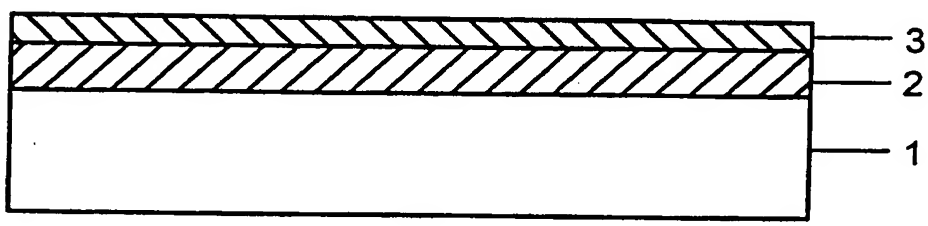
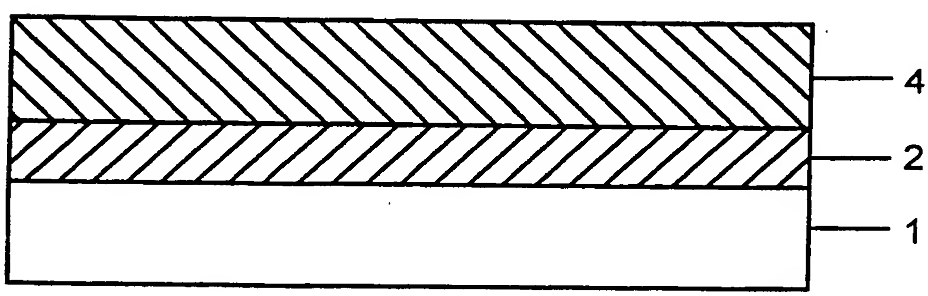


FIG. 3D



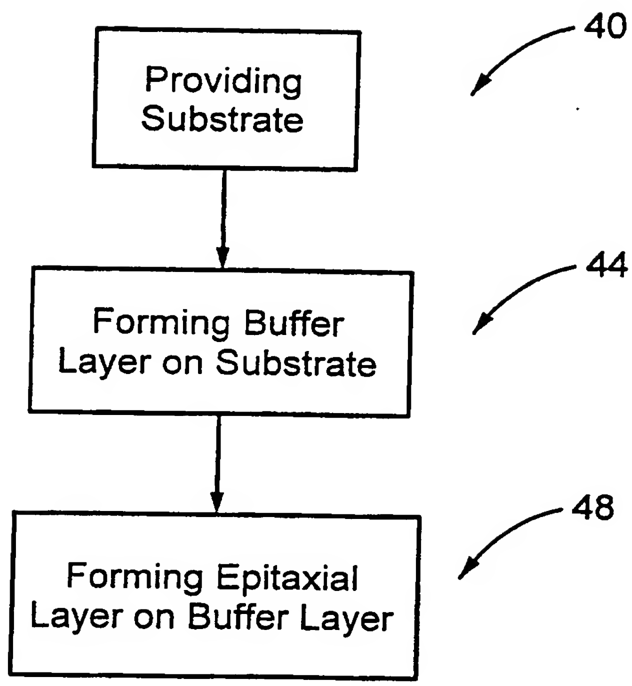

Providing Substrate
40
Forming Buffer Layer on Substrate
44
Forming Epitaxial Layer on Buffer Layer
48

FIG. 4A

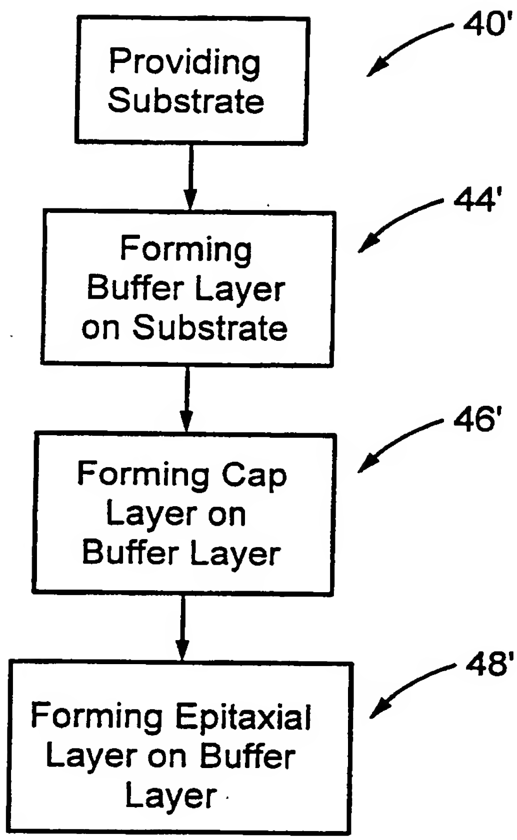

Providing Substrate
40'
Forming Buffer Layer on Substrate
44'
Forming Cap Layer on Buffer Layer
46'
Forming Epitaxial Layer on Buffer Layer
48'

FIG. 4B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/09999

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H01L 21/31
US CL :438/763
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 438/763, 22, 24, 46, 47, 642, 643; 257/79, 84, 85

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO APS EAST search terms: epitaxial, buffer, layer, mocvd, hvpe, cap, deposit$4

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,290,393 A (NAKAMURA) 01 March 1994 (01.03.1994), col. 1-4.	1-8, 13, 20, 23-25 ------ 9-12, 14-19, 26-29
Y --- A	US 5,744,375 A (KAO et al.), 28 April 1998 (28.04.1998), col. 3-6.	9-12, 14-19, 26-29 ------ 21-22, 30-31

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 JUNE 2000	05 JUL 2000

Name and mailing address of the ISA/US	Authorized officer
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